Summary

This report summarizes the results of fiscal year (FY) 1998 groundwater and vadose-zone-monitoring and remediation activities on the Hanford Site. This report is designed to provide a comprehensive interpretation of current groundwater conditions on the site and in adjacent areas, including a description of site hydrogeology, groundwater flow, and groundwater-contaminant distribution. This report fulfills reporting requirements of the *Resource Conservation and Recovery Act of 1976* (RCRA), specific Washington Administrative Codes, and the *Atomic Energy Act of 1954* as implemented by U.S. Department of Energy (DOE) orders. This report also summarizes results of groundwater monitoring conducted to assess the effects of remediation or interim measures conducted in accordance with the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA).

The uppermost aquifer beneath most of the Hanford Site is unconfined and is composed of unconsolidated to semiconsolidated sediments deposited on the basalt bedrock. In some areas, deeper parts of the aquifer are locally confined by layers of silt and clay. Confined aquifers occur within the underlying basalt flows and associated sedimentary interbeds. Groundwater in the unconfined aquifer system generally moves from recharge areas along the western boundary of the site to the east and north toward the Columbia River, which is the major discharge area. This natural flow pattern was altered by the formation of groundwater mounds created by the discharge of large volumes of wastewater at disposal facilities. These mounds are declining, and groundwater flow is gradually returning to earlier patterns.

Water levels are monitored across the Hanford Site and to the east and north of the Columbia River. The purpose of these measurements is to monitor changes in water-table elevations that affect the direction and velocity of groundwater flow and transport of contaminants, and to assess impacts of the changes on monitoring networks. A site water-table map for June 1998 was constructed and used to infer groundwater-flow directions. Water levels over most of the site declined during FY 1998, continuing the trend caused by reduction in liquid effluent disposal. Water levels are also measured in wells completed in the upper basalt-confined aquifer. Several areas showed declines in the confined-aquifer potentiometric surface associated with declines in the water table of the overlying unconfined aquifer.

Vadose Zone

Radioactive and hazardous wastes in the soil column from past intentional liquid waste disposals, unplanned leaks, and underground tanks at the Hanford Site are potential sources of continuing/future groundwater contamination. The continued infiltration of vadose-zone contamination to groundwater depends on contaminant chemistry, stratigraphy, and drainage of water through the vadose zone.

Soil-vapor extraction continued in the 200-ZP-2 Operable Unit as a CERCLA expedited response action to remove the carbon tetrachloride source from the vadose zone. The mix of extraction wells was changed periodically during FY 1998 to improve performance based on a 1997 rebound study. In FY 1998, 777 kg of carbon tetrachloride were removed, totaling 75,490 kg since remediation began in 1992.

In 1998, results from 1997 spectral gamma logging of boreholes surrounding the B-BX-BY single-shell tank farm in the 200-East Area became available. The logging was to detect changes in the distribution of man-made radionuclides in the sediments associated with liquid waste-disposal facilities adjacent to the tank farm. Spectral gamma logging also was performed at boreholes around the Plutonium Finishing Plant liquid-disposal facilities to ascertain any changes in subsurface radionuclide distribution since last logging. Also, baseline characterization logging of all drywells in the BX, C, S, and TY tank farms was completed and the results reported in 1998. In addition, 10 new groundwater-monitoring wells were installed and logged by spectral gamma-ray methods. Historical gross gamma logs from boreholes near SX, BX, BY, and TY tank farms were analyzed to locate mobile radionuclides.

Directional well drilling was tested at two sites. The holes were completed, but boulder gravels at one site presented difficulties in drilling and sampling. Control of drilling fluids also presented an obstacle that must be overcome before using this technique to address vadose-zone contamination.

Sediment samples from new vadose-zone or groundwater wells were collected and analyzed for contaminants and physical properties. A vadose-zone borehole near the SX tank farm was extended to groundwater, and sediments were analyzed for radionuclides. Cesium-137 contamination decreased with depth and was undetectable at the water table.

Groundwater Monitoring of RCRA Treatment, Storage, and Disposal Units

RCRA groundwater monitoring continued at 25 waste management areas. At the end of FY 1998, 17 were being monitored under detection programs and do not appear to be adversely affecting groundwater. The others were monitored under assessment or corrective-action programs. The following summarizes the highlights of RCRA monitoring during FY 1998.

Four single-shell tank waste management areas were monitored under interim-status assessment investigations. Contamination from chemically similar sources such as nearby cribs made it difficult to determine whether the waste management areas (tank farms, transfer lines, diversion boxes) were the source, but the assessment investigations indicate they were. The T and TX-TY single-shell tank farms (200-West Area) have been monitored under an assessment program since 1993 because of elevated specific conductance. An assessment report concluded that the tanks or associated structures probably have contaminated the groundwater with technetium-99. Waste Management Area S-SX (200-West Area) began an assessment program in FY 1996 and appears to have contaminated the groundwater with technetium-99, nitrate, and hexavalent chromium. Waste Management Area B-BX-BY (200-East Area) appears to have contaminated the groundwater with technetium-99.

The 183-H solar evaporation basins (100-H Area) and the 316-5 process trenches (300 Area) were monitored under final-status regulations during FY 1998. The 183-H basins have contaminated the groundwater with technetium-99, uranium, nitrate, and chromium at levels exceeding applicable concentration limits. Corrective action is being addressed by the CERCLA program, and an interim remedial action (pump-and-treat system) for chromium continued operation in FY 1998. Groundwater monitoring to meet RCRA requirements is continuing during the remediation.

The 316-5 process trenches and other nearby sources contaminated groundwater with cis-1,2-dichloroethylene, trichloroethylene, and uranium at levels above their respective concentration limits. However, the corrective-action monitoring plan has not been approved, and monitoring is continuing under the compliance plan. Natural attenuation of the contaminants is the corrective action chosen in the CERCLA record of decision. Groundwater monitoring is continuing in accordance with RCRA to monitor the decline in contaminant concentrations.

Groundwater Contamination

Monitoring wells were sampled during FY 1998 to satisfy requirements of RCRA, CERCLA, Washington Administrative Code, and DOE orders. Approximately 750 wells were sampled during the period.

The extent of major radionuclides at levels above the interim drinking water standards (DWSs) is shown in Figure S.1. Tritium, iodine-129, technetium-99, and strontium-90 were present at levels above the U.S. Environmental Protection Agency (EPA) or State of Washington interim DWSs, and uranium exceeded the EPA's proposed maximum contaminant level (MCL). Minor radiological contamination above the DWS included carbon-14 (100-K Area), cesium-137, and plutonium (200-East Area near the 216-B-5 injection well). Derived concentration guide (DCG)[1] levels were exceeded for strontium-90 in the 100-K, 100-N, and 200-East Areas (near the 216-B-5 injection well), and near the former Gable Mountain Pond. The DCG for uranium was exceeded near U Plant. The DCG for tritium was exceeded in one well near cribs that received effluent from the Plutonium-Uranium Extraction (PUREX) Plant, and in another well near Waste Management Area TX-TY. The DCG for plutonium was exceeded in one well in the 200-East Area (near the 216-B-5 injection well). Cobalt-60 levels exceeded the 100-pCi/L interim DWS in recent years but were below the DWS in FY 1998. Results for individual constituents are summarized below.

The extent of major chemical constituents at levels above the primary MCLs is shown in Figure S.2. Nitrate, carbon tetrachloride, and trichloroethylene were the most widespread. Chloroform, cis-1,2-dichloroethylene, cyanide, fluoride, chromium, and other metals also were present at levels above their MCLs. Tetrachloroethylene exceeded its 5-µg/L MCL in the 300 Area in FY 1998 for the first time since the 1980s. Results for individual constituents are summarized below.

The area of Hanford contaminant plumes with concentrations exceeding an MCL or DWS was estimated to be ~245 million m^2 in FY 1998. This equates to a volume of ~1.4 billion m^3, which is the same as FY 1997. The volume estimate has a high uncertainty because of a lack of knowledge of the vertical extent of contaminant plumes. Plume thickness is estimated to be 20 m, except in the 100, 300, and Richland North Areas, where it is estimated to be 5 m. The porosity of the aquifer is not well-characterized; for the purpose of the calculation, the porosity was assumed to be 30%. The estimate did not include water in the vadose zone.

[1] The DCG is based on a 100-mrem/yr exposure standard and is the amount of an individual radionuclide that would lead to that dose through ingestion under specified intake scenarios.

Tritium

Tritium was present in many Hanford Site waste streams discharged to the soil column and is the most mobile and most widely distributed radionuclide onsite.

Tritium activities at greater than the 20,000-pCi/L interim DWS were detected in FY 1998 in portions of the 100, 200, 400, and 600 Areas. The highest tritium activities in the 200-East Area (exceeding the 2,000,000-pCi/L DCG in one well) continued to be found in wells near cribs that received effluent from the PUREX Plant. Tritium increased suddenly in a 200-West Area well near Waste Management Area TX-TY, exceeding the DCG for the first time in FY 1998.

Tritium in the 400 and 600 Areas can be related to migration from sources in the other operational areas. In particular, tritium migration from sources in the 200-East Area near the PUREX Plant affected that part of the 600 Area downgradient to the east and southeast, the 400 Area, and the 300 Area. This plume discharges to the Columbia River along a stretch that extends from the Old Hanford Townsite to the 300 Area. A smaller plume between the 200-East and 200-West Areas has its source near the 200-West Area's Reduction-Oxidation (REDOX) Plant. This plume is moving relatively slowly because the aquifer has a relatively low permeability and the hydraulic gradient has decreased.

Portions of the 600 Area north of Gable Mountain and Gable Butte are contaminated with tritium at levels below the DWS. The sources appear to be the 100 and 200-East Areas.

Iodine-129

The presence of iodine-129, a moderately low-yield fission product, in groundwater is significant because of its relatively low, 1-pCi/L interim DWS; its long-term releases from nuclear fuel-processing facilities; and its long half-life (16,000,000 years). However, iodine-129's relatively low-fission yield and long half-life limit its activity in Hanford Site groundwater. Iodine-129 is transported in groundwater as the anionic species, which is very mobile. Wastes containing iodine-129 were historically disposed of in the 200 Areas. Extensive plumes at levels above the interim DWS are found in the 200 Areas and in downgradient portions of the 600 Area. The major plume extends toward the southeast from the 200-East Area. A smaller arm of the plume is moving toward the north between Gable Mountain and Gable Butte.

Technetium-99

Technetium-99 is produced as a high-yield fission product and is present in waste streams associated with fuel processing. Technetium is transported in groundwater as a negatively charged species that is highly mobile. Technetium tends to be associated with uranium through the fuel-processing system, but uranium is less mobile in groundwater on the Hanford Site. Technetium-99 activities >900 pCi/L (interim DWS) continued to be observed in the 100-H Area downgradient of the 183-H solar evaporation basins, where fuel-fabrication waste leaked to the ground. The highest technetium-99 activities (annual average of 14,000 pCi/L) were observed in FY 1998 in wells in the 200-West Area, where the largest plume is associated with U Plant, and the plume is migrating to the east into the 600 Area. A groundwater pump-and-treat system is operating near U Plant to contain the plume. Equally high activities were

observed in a well near Waste Management Area T. Technetium-99 is also elevated in wells monitored for the B-BX-BY, S-SX, and TX-TY single-shell tank farms. These sites are undergoing RCRA assessment investigations.

Elevated technetium-99 levels apparently associated with the BY cribs (200-East Area) continued to be observed in FY 1998. A well formerly used for groundwater extraction in treatability testing that contained up to 9,910 pCi/L of technetium-99 in 1995 contained only 398 pCi/L in FY 1998. The maximum average annual level of technetium-99 detected in the area north of the 200-East Area in FY 1998 was 2,200 pCi/L.

A well completed in the confined aquifer near the BY cribs had technetium-99 at levels above the 900-pCi/L DWS in FY 1998 (average of 1,500 pCi/L, which is within the historical range). The well also had elevated cobalt-60 and cyanide, though levels were less than the applicable standards.

Uranium

There are numerous potential sources of uranium release on the Hanford Site, including fuel fabrication, fuel processing, and uranium recovery from separations activities. Uranium mobility is dependent on Eh, pH, and the presence of carbonate; its migration is slower than that of tritium and technetium-99. At the Eh/pH conditions found in the unconfined aquifer, U(VI) is the most mobile state.

The EPA proposed a 20-µg/L MCL for uranium. Uranium was detected at concentrations above this proposed MCL in the 100-H, 200, and 300 Areas. One well in the 100-F Area that exceeded the standard in previous years was not sampled in FY 1998. Contamination in the 100-H and 200-East Areas is very localized. The highest concentrations detected in FY 1998 (exceeding the DCG) were in the 200-West Area near the 216-U-1 and 216-U-2 cribs, and this plume extends into the 600 Area to the east. Like technetium-99, this plume is being contained by a pump-and-treat system.

Another area of elevated uranium concentrations is observed in the 300 Area, downgradient of the 316-5 process trenches and ponds. Uranium contamination appears to be moving from the vicinity of the process trenches toward the southeast. An expedited response action was performed on the trenches in mid-1991 to reduce the uranium source in that area. Use of the trenches for disposal of cooling water was resumed after the expedited response action was completed. Uranium levels decreased sharply after the expedited response action but rose again after 1994, when discharges and associated dilution ceased.

Strontium-90

Strontium-90 is produced as a high-yield fission product and is, therefore, present in waste streams associated with fuel processing; it was released also by fuel-element failures during reactor operations. Strontium-90 is of concern because of its moderately long half-life (28.8 years), its potential for concentrating in bone tissue, and the relatively high energy of the beta decay from its yttrium-90 radioactive decay product. In FY 1998, strontium-90 activities exceeded the 8-pCi/L interim DWS in wells in all of the 100 and 200 Areas and near the former Gable Mountain Pond. Strontium-90 exceeded the 1,000-pCi/L DCG in wells in the 100-K, 100-N, and 200-East Areas and near the former Gable Mountain Pond.

The most widespread, high strontium-90 activities (greater than the DCG) continued to be observed in the 100-N Area. The overall extent of the 100-N Area strontium-90 plume is not increasing perceptibly. A pump-and-treat system operates in the 100-N Area to reduce the flux of strontium-90 to the Columbia River.

Carbon-14

Carbon-14 exceeded the 2,000-pCi/L interim DWS in two small plumes near waste-disposal facilities adjacent to the K-West and K-East Reactor buildings. The maximum average activity in FY 1998 was 33,000 pCi/L.

Cobalt-60

Cobalt-60 is a neutron activation product typically associated with wastes generated by the processing of irradiated fuel or with reactor-cooling water. Cobalt-60 is predominantly present as a divalent cation that is strongly adsorbed onto onsite sediments and is rarely observed in groundwater unless complexed by other chemicals. North of the 200-East Area, in an area that is affected by waste disposed to the BY cribs, wells consistently show the presence of detectable cobalt-60, but levels have declined because of its relatively short half-life (5.3 years). In FY 1998, the maximum annual average cobalt-60 detected in this vicinity remained below the 100-pCi/L interim DWS. Cobalt-60 in this area appears to be highly mobile, probably because of the presence of a soluble cobalt-cyanide (or ferrocyanide) complex associated with the plume originating in the BY cribs.

Very low levels of cobalt-60 have been detected in groundwater downgradient of the PUREX Plant as far as the Old Hanford Townsite in the past. This indicates that cobalt-60 may have been mobilized by a complexing agent other than cyanide in some Hanford Site wastes. Levels have been below detection limits in FY 1997 and FY 1998.

Cesium-137

Cesium-137 is produced as a high-yield fission product, is present in waste streams associated with fuel processing, and has been released in reactor areas by fuel-element failures. The activity of cesium-137 in FY 1998 reached 2,200 pCi/L in a well near the 216-B-5 injection well, which is in line with the historical trend for the well. The interim DWS for cesium-137 is 200 pCi/L.

Cesium-137 is a potential contaminant of concern at the S and SX single-shell tank farms because it was detected in vadose-zone sediments in FY 1996. Low activities of cesium-137 continued to be detected in one groundwater well in this area, but it appears that the contamination is dominantly sorbed to particulate matter and does not seem to be a significant groundwater contaminant.

Plutonium

Plutonium was present in waste streams associated with fuel processing. The DCG for plutonium-239 is 30 pCi/L. There is no explicit interim DWS for plutonium-239; however, the gross alpha MCL of 15 pCi/L is applicable. Alternatively, if the DCG (which is based on a 100-mrem dose standard) is

converted to the 4-mrem dose equivalent used for the interim DWS, 1.2 pCi/L would be the relevant guideline. Plutonium generally binds strongly to sediments, so its mobility in groundwater is limited.

The only significant detection of plutonium in FY 1998, as in previous years, was associated with the 216-B-5 injection well in the 200-East Area. The maximum plutonium-239/-240 activity detected near this injection well in FY 1998 was 63 pCi/L. There was no significant difference in activities from filtered and unfiltered samples. Plutonium had been detected at low levels in the past in a well ~150 m northwest of this injection well, but was below the detection limit in FY 1997 and FY 1998.

Nitrate

Nitrate contamination in the unconfined aquifer system reflects the extensive use of nitric acid in decontamination and chemical-processing operations. Like tritium, nitrate was present in many waste streams and is mobile in groundwater. Additional sources of nitrate are located offsite to the south and west.

Nitrate was measured at concentrations greater than the MCL (45 mg/L as the NO_3^- ion) in wells in all operational areas. Although elevated nitrate levels were found throughout the extensive plume that emanates from the vicinity of the PUREX Plant in the 200-East Area, only proportionally small areas contained nitrate at levels above the MCL. Extensive nitrate contamination extends into the 600 Area from the vicinity of U Plant in the 200-West Area. A large nitrate plume in the 200-West Area is located near T Plant, while smaller amounts of contamination are found near the Plutonium Finishing and REDOX Plants. Two relatively small areas greater than the MCL are observed near the 400 Area and the Washington Public Power Supply System. Nitrate contamination in the Richland North Area apparently has a source off the Hanford Site.

Chromium

A major source for chromium was the sodium dichromate used as a corrosion inhibitor in cooling water for reactors in the 100 Areas. Chromium was also used for decontamination in the 100, 200, and 300 Areas and for oxidation-state control in the REDOX Plant processes in the 200-West Area. Chromium was elevated in each of the 100 Areas, but the major plumes exceeding the 100-µg/L MCL are related to operations in the 100-K, 100-D, and 100-H Areas and portions of the 600 Area between. Hexavalent chromium was detected in the Columbia River substrate adjacent to these areas and is a hazard to some aquatic life. Therefore, interim actions are under way to pump and treat groundwater in these areas to reduce the amount of chromium reaching the river. The chromium plumes are not well-defined in the area east of the 100-K Area, the southwestern 100-D Area, and in the area between the 100-D and 100-H Areas.

Chromium concentrations were also found at levels above the 100-µg/L MCL near T Plant and the 216-S-10 pond and ditch in the 200-West Area. Chromium continued to exceed the MCL in one well south of the 200-East Area. Other wells in the area also have elevated chromium, though levels are below the MCL. The source of this plume was not established.

Carbon Tetrachloride

Carbon tetrachloride contamination was found in FY 1998, as in previous years, to be above the 5-µg/L MCL beneath much of the 200-West Area. The plume extends beyond the area boundary and forms the most widespread organic contaminant plume onsite. The contamination is principally from waste-disposal operations associated with the Plutonium Finishing Plant, where it was used in plutonium processing. Concentrations in the central part of the plume remained above 2,000 µg/L in FY 1998. A groundwater pump-and-treat system is operating in this area to prevent further movement of the central portion of the plume. There appears to be a shift in the maximum concentrations toward the pumping wells, and the treated water is displacing the plume in the vicinity of the injection wells, located west of the area. The total area of the carbon tetrachloride plume at the top of the unconfined aquifer in FY 1998 (5-µg/L contour) was ~11.4 km^2, compared to ~11.3 km^2 in FY 1997. In some areas, concentrations of carbon tetrachloride decrease with depth, but data collected in recent years indicate that in other areas carbon tetrachloride is present at higher concentrations deeper in the suprabasalt sediments than at the water table. Therefore, the extent of the plume at the water table may not reflect the extent in deeper parts of the aquifer.

Chloroform

The 200-West Area chloroform plume is associated with the carbon tetrachloride plume and is believed to be a degradation product of carbon tetrachloride. The MCL for chloroform is 100 µg/L (total trihalomethanes).

Trichloroethylene

Trichloroethylene (TCE) was commonly used on the Hanford Site in the 1960s and 1970s as a degreasing compound. TCE was detected at concentrations greater than the 5-µg/L MCL in FY 1998 in wells in the 100-K, 100-F and adjacent upgradient 600 Areas, 200-West, 300, and Richland North Areas. Concentrations of TCE were also detected in wells near the Solid Waste Landfill but were below the MCL.

Concentrations of TCE exceeded the MCL in the 200-West Area to the west of T Plant and to the east of U Plant. It was not detected near the REDOX Plant in FY 1998, unlike previous years. Some TCE at levels above the MCL is also associated with the carbon tetrachloride plume near the Plutonium Finishing Plant.

The 5-µg/L MCL for TCE was exceeded in two of the point-of-compliance wells for the 1100-EM-1 Operable Unit and in other wells near Siemens Power Corporation and Horn Rapids Landfill. The plume appears to be moving toward the northeast.

cis-1,2-Dichloroethylene

Concentrations of cis-1,2-dichloroethylene continued to increase in a well that monitors the bottom of the unconfined aquifer near the 316-5 process trenches in the 300 Area. The average cis-1,2-dichloroethylene concentration in this well in FY 1998 was 156 µg/L (MCL = 70 µg/L). The source of this constituent is believed to be anaerobic biodegradation of TCE.

Tetrachloroethylene

A plume of tetrachloroethylene was detected in the 300 Area in FY 1998. Concentrations exceeding the 5-µg/L MCL appeared simultaneously in six wells downgradient of the 316-5 process trenches in May 1998. Concentrations increased in July (maximum of 38 µg/L), and decreased again by September as the plume appeared to be moving downgradient.

Cyanide

A cyanide plume is present north of the 200-East Area and is believed to have originated from wastes containing ferrocyanide that were disposed in the BY cribs. Wells containing cyanide often contain concentrations of several radionuclides, including cobalt-60. Cobalt-60 appears to be chemically complexed and mobilized by cyanide or ferrocyanide. The maximum average annual concentration of cyanide detected in FY 1998 was 333 µg/L, exceeding the 200-µg/L MCL.

Fluoride

Fluoride was detected at the primary 4-mg/L MCL in a small plume near the T Plant waste-disposal facilities (200-West Area). Three wells in the Richland North Area also exceeded the MCL, and the contamination is believed to come from an offsite source.

Ingestion Dose and Risk Estimates

Results of groundwater monitoring are compared to the DWSs for individual radiological constituents. These interim DWSs use the methodology set out in 40 CFR 141, 40 CFR 142, and 40 CFR 143 to estimate the concentration in water that could result in a potential radiological dose of 4 mrem/yr from consumption of each individual constituent. Similarly, DCGs provide estimates of activities that could result in a 100-mrem/yr dose as defined in DOE Order 5400.5. However, the potential dose is actually the sum of the doses from the individual constituents. An estimate of this cumulative dose, which could result from consumption of groundwater from different onsite locations, can be calculated from the extent of contamination.

Figure S.3 shows the cumulative dose estimates from ingestion of groundwater from the unconfined aquifer system on the Hanford Site. These estimates were made by summing the interpolated carbon-14, strontium-90, technetium-99, iodine-129, cesium-137, plutonium, tritium, and uranium activities in groundwater. The automatic interpolation process sometimes resulted in peak grid values that were lower than the measured maximum values because it averaged in other lower values. In these cases, the value at the grid node closest to the measured peak value was increased to match the measured peak. Factors to convert activities to ingestion dose equivalents were taken from DOE Order 5400.5. The dose presented in Figure S.3 represents the cumulative dose equivalent from all major radionuclides in Hanford Site groundwater.

The dose estimates presented in Figure S.3 show that areas above the 100-mrem/yr dose standard are restricted to localized parts of the 100-K, 100-N, and 200 Areas. Areas above 4 mrem/yr are more restricted than the area above the interim DWS for individual constituents because the dose map used

more recent conversion factors than those used in calculating the interim DWSs. Dose estimates for portions of the 100, 200, 300, and 600 Areas exceed 4 mrem/yr.

Figure S.4 illustrates the estimated lifetime incremental cancer risk that would be experienced by a person drinking water contaminated with chemicals and radionuclides at concentrations that have been measured in groundwater across the Hanford Site. Cancer-risk estimates were made by summing interpolated groundwater concentrations of the radionuclides listed above plus carbon tetrachloride, chloroform, trichloroethylene, cis-1,2-dichloroethylene, nitrate, and hexavalent chromium. The calculation assumes that a person weighing 70 kg consumes 2 L of groundwater every day for 30 years (DOE/RL-91-45, Rev. 3; IRIS 1997). Cancer risks exceeding 0.0001 are present in portions of the 100, 200, 300, and 600 Areas, and this contour closely resembles the cumulative dose map (see Figure S.3). An additional area of cancer risk >0.0001 is observed in the 200-West Area, a result of the carbon tetrachloride plume.

Figure S.5 shows the estimated hazard quotient that would be experienced by an individual drinking water contaminated with chemicals at concentrations that have been measured in groundwater across the Hanford Site. The hazard quotient relates the potential human health hazards associated with exposure to noncarcinogenic substances or carcinogenic substances with systemic toxicities other than cancer (in Hanford Site groundwater, these include nitrate, hexavalent chromium, uranium, and strontium). The calculation assumes that a person weighing 70 kg consumes 2 L of groundwater every day for 30 years (DOE/RL-91-45, Rev. 3; IRIS 1997). The only part of the Hanford Site with a >5 hazard quotient is a small portion of the 200-West Area. Hazard quotients >0.3 are present in all of the operational areas and in parts of the 600 Area, primarily those areas with nitrate contamination.

Groundwater Modeling

Numerical simulations of groundwater flow and contaminant movement are used to predict future conditions and to assess the effects of remediation systems. One sitewide model and several local-scale models were applied to the Hanford Site in FY 1998.

The sitewide three-dimensional model was used during FY 1998 to support the composite analysis of the Hanford Site. The composite analysis involved simulation of future transport of radioactive contaminants from all sources expected to exist on the Hanford Site following site closure. Site closure was assumed to occur in 2050, followed by a 1,000-year compliance period.

Over an ~300-year period following site closure and the elimination of wastewater discharges to the ground at the Hanford Site, the water table is predicted by the model to decline significantly and return to near pre-Hanford Site conditions. Over this period, the water table is predicted to drop as much as 11 m beneath the 200-West Area near the 216-U-10 pond and 7 to 8 m beneath the 200-East Area near 216-B-3 pond.

Other groundwater models were applied in the design and evaluation of pump-and-treat activities aimed at remediation of contaminated groundwater in the 100 and 200-West Areas. These models were used to describe the capture and injection zones for extraction and injection wells, respectively, and to estimate the area affected by the pump-and-treat operations at different times.

Groundwater Remediation

Groundwater remediation conducted in accordance with CERCLA was performed at the following sites:

- 100-KR-4 Operable Unit – An interim action to address chromium contamination near the 116-K-2 trench was initiated in FY 1997 and continued in FY 1998. Groundwater is extracted from six wells between the trench and the river, treated to remove chromium, and injected into wells upgradient of the trench. Significant portions of the plume are being captured and the mass of chromium in the aquifer is being reduced.

- 100-NR-2 Operable Unit – Groundwater continued in FY 1998 to be extracted from wells near the 1301-N liquid waste-disposal facility, treated to remove strontium-90, and injected into wells near the 1325-N liquid waste-disposal facility. The extraction wells create a hydraulic barrier to reduce the volume of contaminated groundwater reaching the river.

- 100-D Area chromium hot spot – A demonstration of in situ redox manipulation technology continued in FY 1998 in the 100-D Area to determine the feasibility of using the technology to reduce hexavalent chromium in groundwater. The project's goal is to create a permeable treatment zone in the subsurface where chemical-reducing agents will turn the highly soluble hexavalent chromium to an insoluble state. Groundwater chemistry in the treatment zone shows dramatic effects of the reduction. It is too soon to see the effects on groundwater farther downgradient.

- 100-HR-3 Operable Unit, 100-D Area – An interim action pump-and-treat system was put into operation in FY 1997 and continued in FY 1998. The system removes chromium-contaminated groundwater from wells near the river and pipes it to the 100-H Area for treatment and injection. The hydraulic effects of groundwater extraction result in containment of the plume along ~400 m of shoreline.

- 100-HR-3 Operable Unit, 100-H Area – An interim action pump-and-treat system began to operate in FY 1997 and continued in FY 1998. The system removes chromium from wells around the 183-H solar evaporation basins, treats it to remove chromium, and injects the water into wells in the southwestern part of the area. Most of the plume is being captured, but a portion continues to pass between the extraction wells into the river.

- 200-UP-1 Operable Unit – An interim action pump-and-treat system, designed to contain and treat the elevated technetium-99 and uranium, continued to operate in FY 1998. The most notable success in FY 1998 was the reduction of technetium-99 to below the remediation goal of 9,000 pCi/L in all but 2 wells. Uranium concentrations remained above the remediation goal of 480 µg/L in almost all wells, even after treatment of 338,300,000 L and 3 years of operation.

- 200-ZP-1 Operable Unit – An interim action pump-and-treat system continued to operate to prevent further movement of carbon tetrachloride, chloroform, and trichloroethylene from the high-concentration portion of the carbon tetrachloride plume and to reduce contaminant mass. Treatment of the contaminated water resulted in the removal of 1,212 kg of carbon tetrachloride in FY 1998. Since initiation of pump-and-treat operations (August 1994) through September 1998, >614,800,000 L

of water have been treated, resulting in removal of 2,099 kg of carbon tetrachloride. The system is containing and capturing the high-concentration portion of the plume.

Well Installation, Maintenance, and Decommissioning

Ten new wells were installed for RCRA groundwater monitoring in FY 1998. Seven of these replaced wells that are going dry because of a declining water table. The other three wells supplemented assessment or detection networks to maintain adequate monitoring coverage.

Approximately 190 well-maintenance activities were carried out during FY 1998. These activities included well or pump repair, cleaning, and maintenance.

The schedule for well decommissioning is driven by potential risk for a well to provide a contaminant pathway to deeper zones and the long-range environmental restoration schedule. In general, areas adjacent to the Columbia River are to be remediated first. In FY 1998, 28 Hanford Site wells were decommissioned. They were located in the 100, 200, and 600 Areas, and north of the Columbia River.

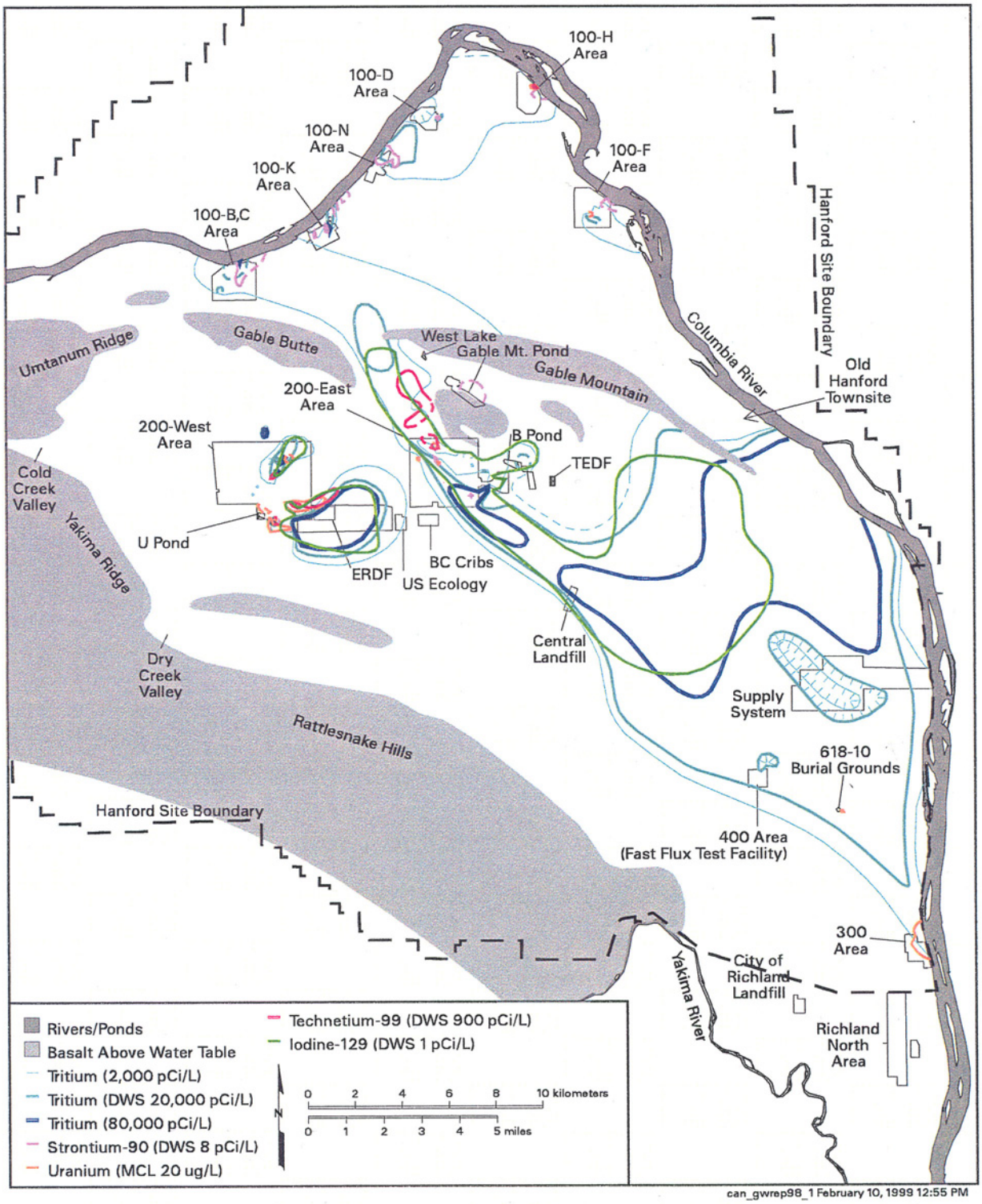

Figure S.1. Distribution of Major Radionuclides in Groundwater at Activities Above Maximum Contaminant Levels or Interim Drinking Water Standards, Fiscal Year 1998

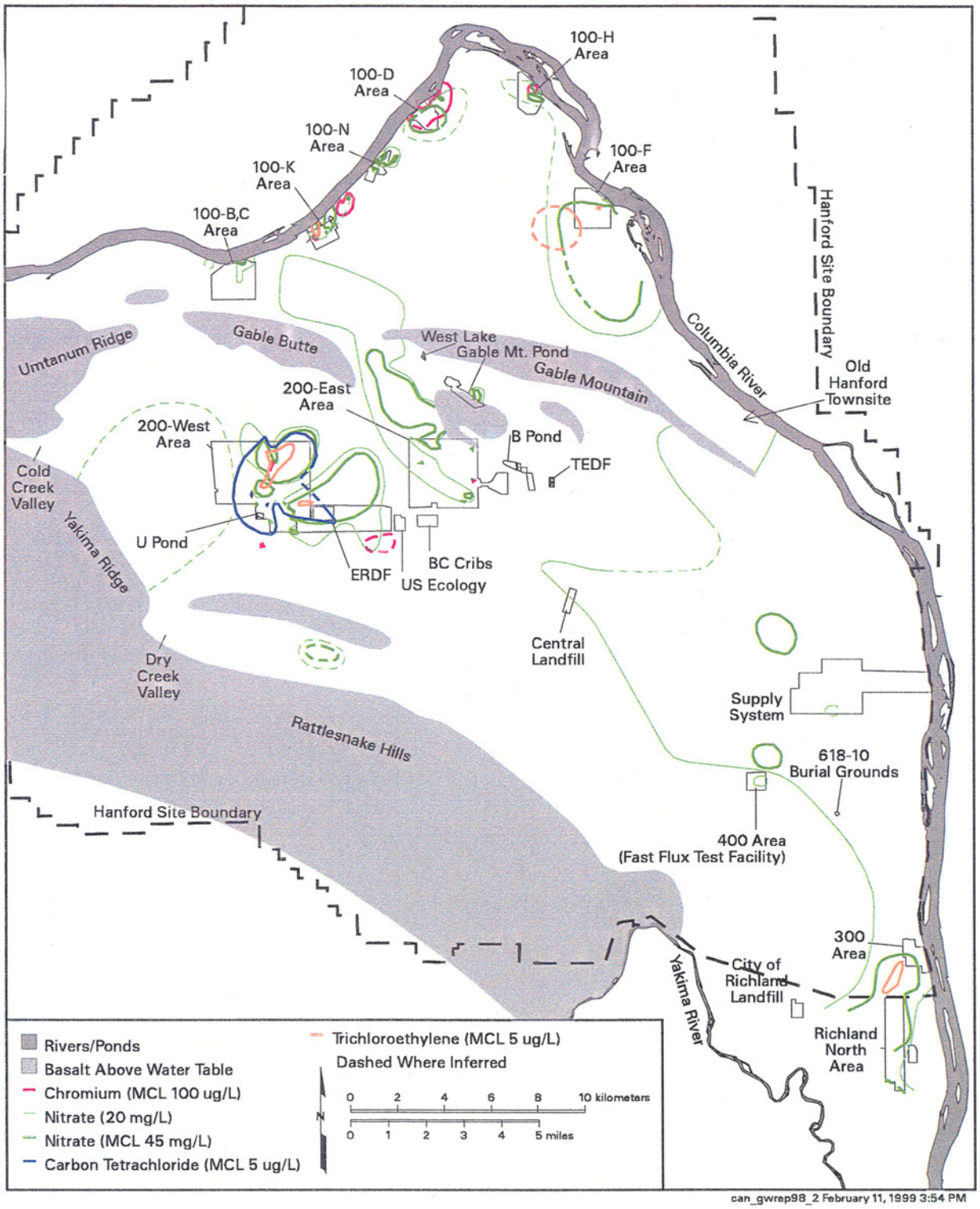

Figure S.2. Distribution of Major Hazardous Chemicals in Groundwater at Concentrations Above Maximum Contaminant Levels, Fiscal Year 1998

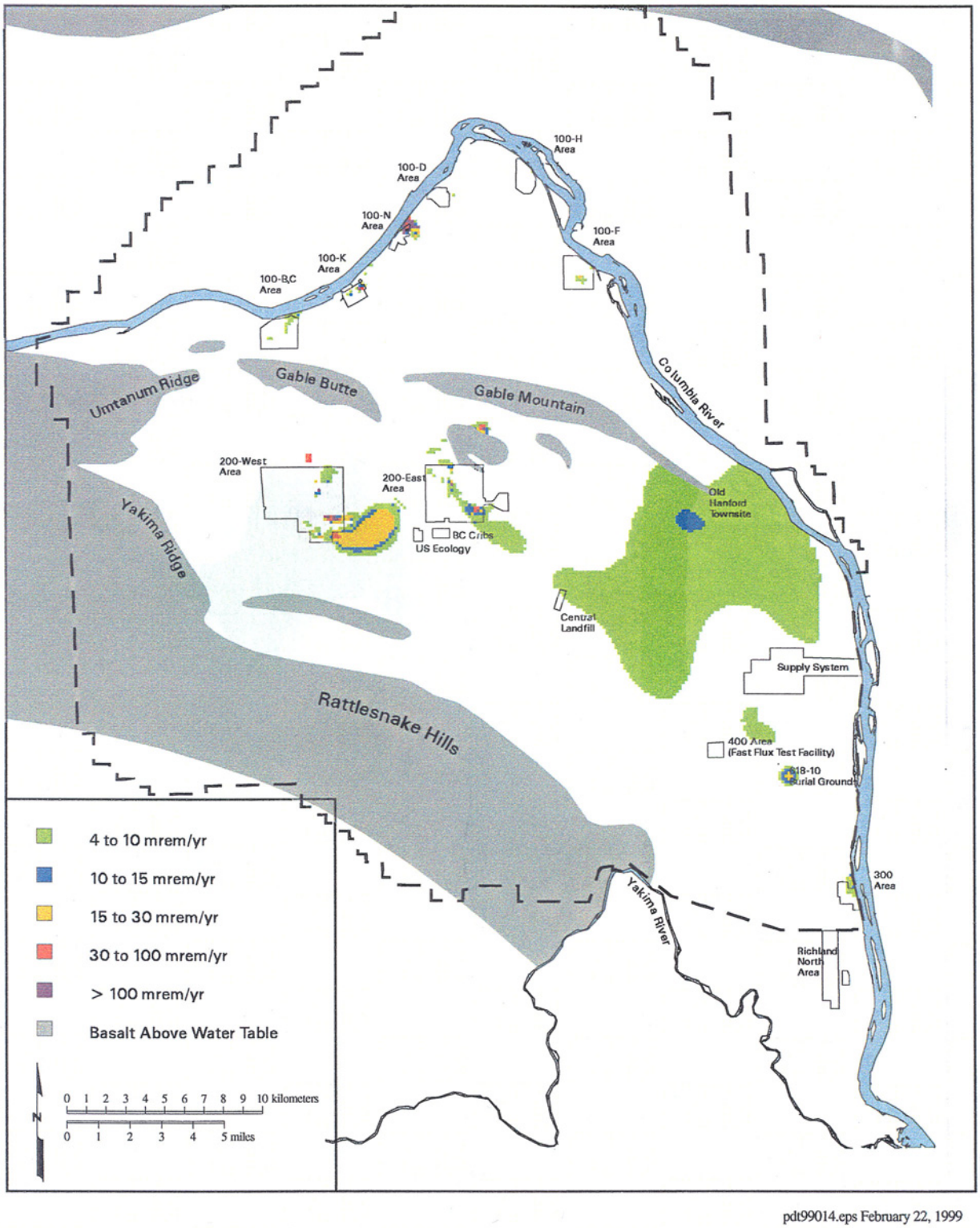

Figure S.3. Potential Dose Estimates from Ingestion of Groundwater, Fiscal Year 1998

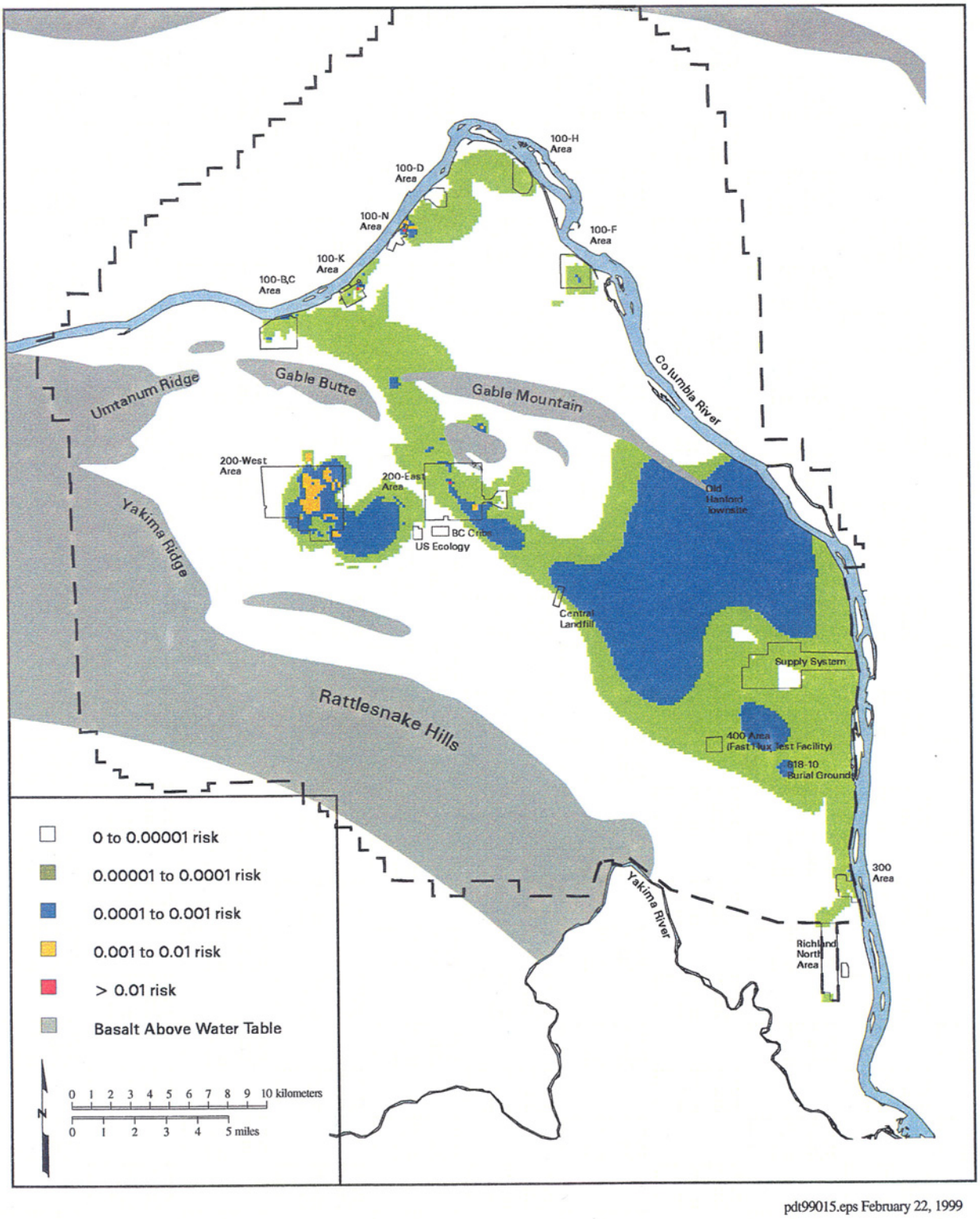

Figure S.4. Cancer-Risk Estimates from Ingestion of Groundwater, Fiscal Year 1998

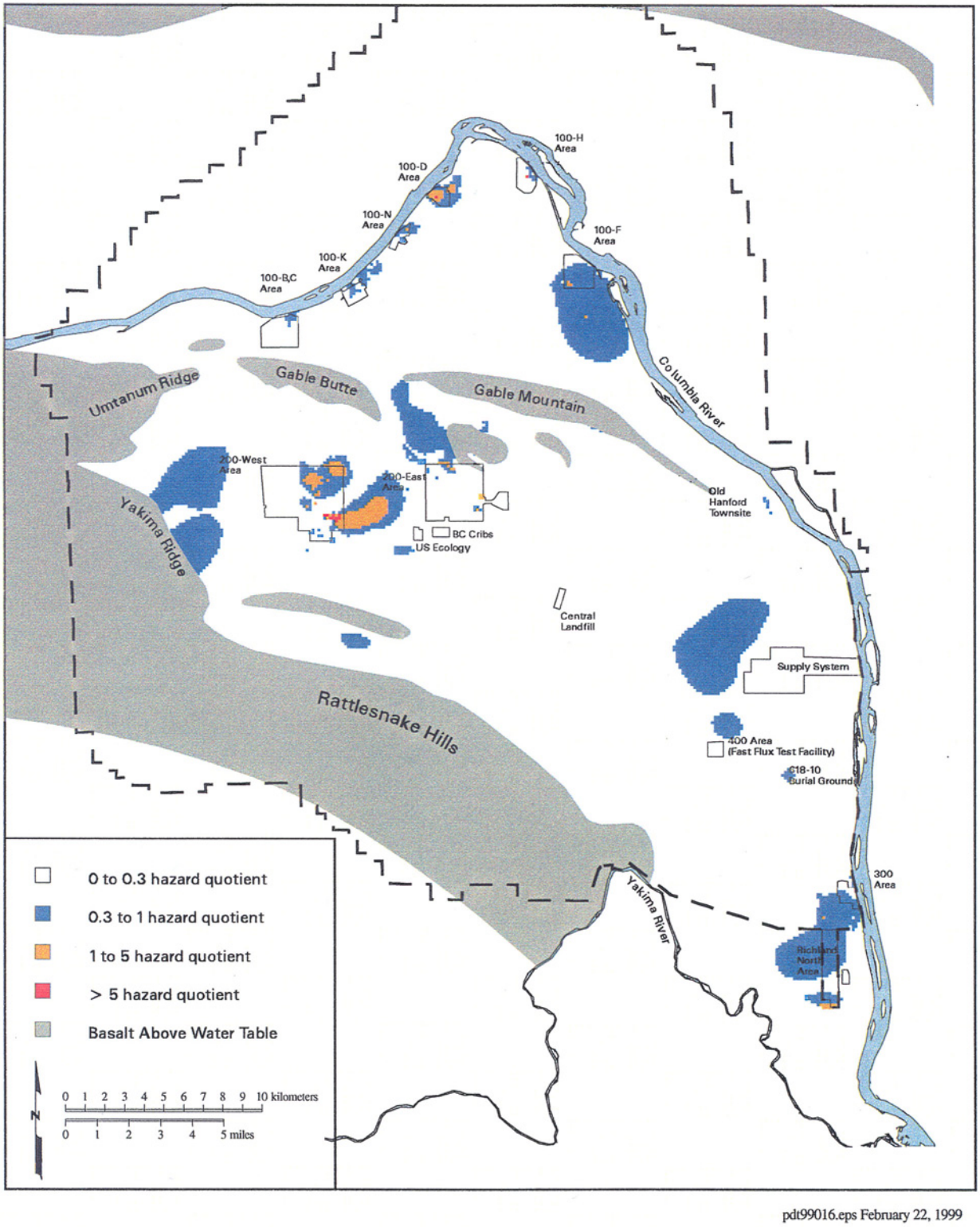

Figure S.5. Hazard Quotient Estimates from Ingestion of Groundwater, Fiscal Year 1998